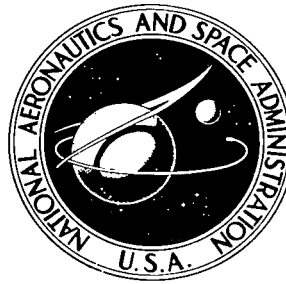


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by Emmett C. Lampkin and Robert J. Randle

*Ames Research Center
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SUMMARY

Recent investigations of sextant sighting performance have been concerned with the effects of telescope factors, the influence of various target background contrasts, and the effect of motion of either the target or the observer. Additional studies have examined star recognition and identification in relation to the field of view. The present study was concerned with two additional variables: (1) sextant sighting training schedules and (2) use of simulated monochromatic star targets.

Fifteen male college students were divided into three equal groups and trained for varying lengths of time on a star-star sextant sighting task. A trend analysis revealed significant improvement in performance ($p < 0.001$) for all groups through the fifth day of training. There were no differences between groups compared through the fifth day. One group was trained for an additional five days, but, at the end of that period, showed no significant change from the fifth day.

The same subjects later performed a star-star sextant sighting task using various combinations of monochromatic stars. Performance variability decreased significantly ($p < 0.01$) when sightings were made using two red stars.

INTRODUCTION

In repetitious tasks such as sextant sighting training, one important objective is to judge as closely as possible when the trainee has reached his performance asymptote. Training beyond this point does not improve the performance of the trainee and, in fact, may be detrimental to his proficiency by increasing boredom and decreasing his interest in the task. Even subjects whose performance does not deteriorate with overtraining seldom show any significant improvement, even months later. In a pilot study, it was found that the best daily training schedule using a gimbal-mounted sextant is 3 sets of 16 sightings each per day, with a few minutes rest between sets. Previous sextant sighting experiments (refs. 1-4) suggest that the average amount of training needed to reach asymptotic performance might be somewhere between 4 and 8 days. Most of the subjects appeared to have reached their performance

asymptote by the fifth day of training, but around the eighth day many subjects showed a performance decrement.

The present study was designed to investigate both ends of the performance range found in the previous data. Five and ten-day training schedules were used. By doubling the five-day training period, considered to be the optimum, it was felt that the time needed by any subject to reach asymptote would be included; an additional five days should allow time for any deterioration in performance to appear. A group of experienced subjects was also included to find out how much retraining is required for experienced subjects to regain their performance asymptote. The selection criterion for experienced subjects was that they must have participated in at least two previous sextant sighting experiments in which the same apparatus was used as in this study to assure that the subjects were familiar with the apparatus and the experimental procedures used.

One important requirement in space navigation is the rapid acquisition of correct star targets. Previous studies have examined star recognition and identification in relation to the field of view (refs. 5 and 6). If stars with distinctive colors, for example, red or green, can provide the same accuracy as white stars, then acquisition time and correct identification might be greatly improved. Also, it is possible that using two stars of different color might aid in the tasking in that when the subject superimposed the stars he would see a third color. If the two stars are equal in intensity and apparent size, there should be little trace of the original two colors, thus providing instant feedback on performance. It was hypothesized that using two differently colored stars might yield better performance because of this additional feedback. Two questions considered were: (1) How is sextant sighting performance affected when both star targets are the same color, in comparison with the usual white light star? (2) Is the sextant sighting performance improved when two stars of different color are used?

METHOD

Apparatus

The sighting instrument used was a standard marine sextant, gimbal mounted (fig. 1) to allow the sextant to be rotated freely about its optical axis (primary line of sight). The sextant and the simulated stars are described in detail in reference 1. Mounting the sextant in this manner eliminates the usual requirement that the subject hold the instrument in his hand, and thus minimizes variability due to individual differences in hand-arm strength and fatigue. A digital shaft encoder was attached to the vernier knob of the sextant (see figs. 1 and 2). The encoder was, in turn, connected to a remote readout station monitored by the experimenter who gave feedback to the subjects after they completed each sighting. Each angular sighting was printed (in seconds of arc) on paper tape when the subject pressed a foot switch, and the number was read to the subject.

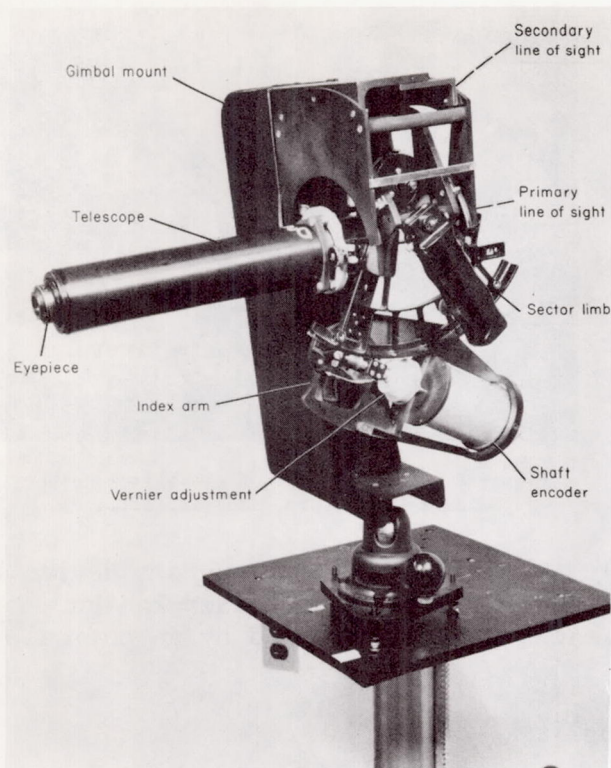


Figure 1.- Standard marine sextant gimbal mounted with digital shaft encoder and special telescope.

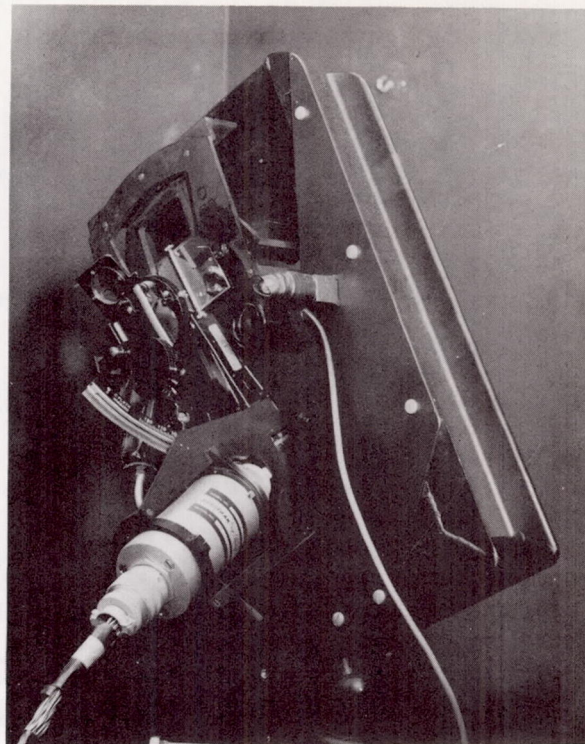


Figure 2.- Standard marine sextant showing digital shaft encoder.

A specially designed telescope was substituted for the standard monocular supplied with the sextant to obtain higher quality target images (see figs. 1 and 3). To increase the clarity of the star images even more, a one-half-diameter of the objective lens) aperture stop was placed in front of the objective lens. Reference 1 provides data on the increased quality obtained when the special telescope is substituted for the regular monocular and, also, discusses the details of the telescope itself.

Stars were simulated by projecting a point source of light onto a parabolic mirror. The point source was produced by placing a 2.5-V (dc) grain-of-wheat lamp behind a 0.0005-inch-diameter aperture and positioning it at the focal point of the parabolic mirror. This resulted in a collimated image of the aperture being projected, which the subjects perceived as a star at infinity.

Four combinations of monochromatic stars were used: red-red, blue-blue, white-white, and red-green. Star intensity was set at plus one visual magnitude (+1.0) for all conditions. Kodak Wratten gelatin filters were used to

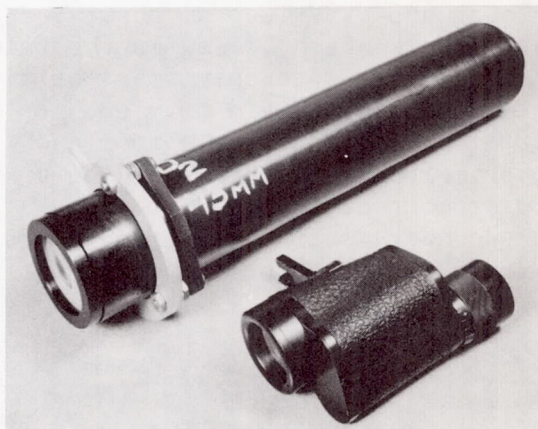


Figure 3.- Comparison of the standard sextant monocular and the specially designed high-power telescope.

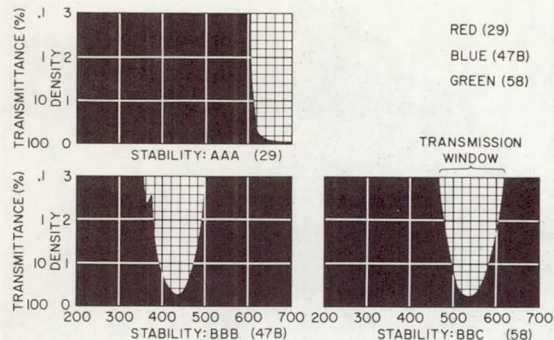


Figure 4.- Curves for the Kodak Wratten filters used to make the monochromatic targets.

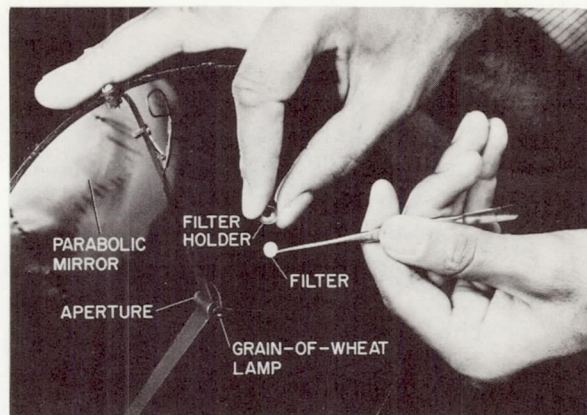


Figure 5.- Closeup view of the filter holder, grain-of-wheat lamp, and sample filter.

produce the monochromatic stars (fig. 4). Figure 5 shows the support device of the point source in detail. The 2.5-V (dc) grain-of-wheat lamp had an approximate color temperature of 2200° K at 2.0 V, as measured by an optical pyrometer.

Sighting Task

Figure 6 shows the major parts of the standard marine sextant and may be a useful reference for the following discussion of the standard sighting task used by all subjects. The same sighting method was used during both the training and experimental phases, and required the subject to superimpose two star targets which he saw in the telescope field of view. Each sighting began with the secondary star positioned above the stationary star, as seen in the telescope field of view. By turning the vernier adjustment, the subject moved the indexing mirror and the secondary star appeared to move toward the primary star in his field of view. Subjects were instructed to rotate the vernier control in one direction only to reduce mechanical backlash errors. The secondary star was allowed to be brought to superimposition only from a position above the primary. If the subject decided he had brought the secondary

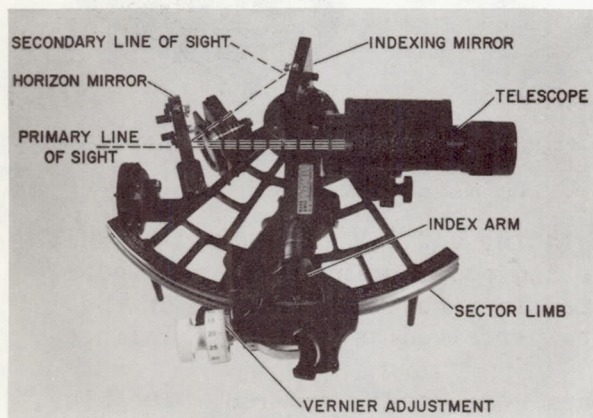


Figure 6.- Standard marine sextant.

star down too far, he was required to move the secondary back to the starting position and sight again. The experimenter monitored the digital readout and was able to assure that every subject started each sighting with the secondary star positioned at least 5 minutes of arc above the primary. When the stars appeared to be superimposed, the subject oscillated the sextant about its optical axis, and the secondary star appeared to swing in an arclike manner. In this way, the subject was able to confirm how close he had brought the targets to superimposition.

Subjects

Fifteen male students from nearby colleges were selected as subjects on the basis of satisfactory scores on standard vision tests. A Bausch and Lomb orthorater was used to test visual acuity (ref. 7), and the Ishihara color test for color perception (ref. 8). A satisfactory score consisted of (1) uncorrected visual acuity equivalent to Snellen 20/20 or better, and (2) no color deficiencies. The subjects were divided into three groups of five. Groups I and II were naive, and group III, previously trained subjects who had participated in at least two previous sextant sighting experiments using the same apparatus employed in this study.

Training

Group I received 5 days of training, group II, 10 days, and group III, 5 days of refresher training. Each subject made 48 sightings per day - 3 sets of 16 sightings - with approximately 20 minutes rest between sets.

Sighting on the Monochromatic Stars

One color condition was run per day with 16 sightings taken per condition by each subject. Each color condition was repeated once for a total of 8 days. Conditions were randomized in two blocks of four (of each color) to offset serial, or learning, effects.

RESULTS AND DISCUSSION

Training

Table I, a summary of the analysis of variance for all groups through training day five, shows no significant differences between subjects or experimental conditions. In addition, a trend analysis (ref. 9, p. 227) compared all groups across the first five days of training. Table II summarizes

TABLE I.- ANALYSIS OF VARIANCE
SUMMARY

(For all groups, training days
1-5)

Source	df	MS	F
Trials	4	0.94	N.S.
Subjects	4	6.62	N.S.
S's×trials	16	.95	
Total	24		

TABLE II.- ANALYSIS OF VARIANCE SUMMARY
FOR THE TREND ANALYSIS

Source	df	MS	F
A: Groups	4	7.06	N.S.
Error	20	8.63	
B: Sessions	4	64.92	45.72 ^a
A×B: Groups×Sessions	8	2.80	N.S.
Error (b)	88	1.42	
Total	124		

^ap < 0.001.

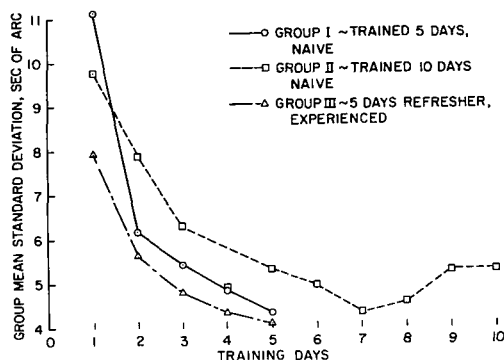


Figure 7.- Average group training performance.

TABLE III.- F TESTS FOR LINEAR AND QUADRATIC COMPONENTS OF THE TRAINING CURVES

Component	F
Linear	151.39 ^a
Quadratic	28.97 ^b

^a $p < 0.001$.

^b $p < 0.005$.

that analysis of variance. Figure 7 shows that performance for all groups improved very significantly ($p < 0.001$)¹ during the first five days. Table III shows the F tests for the linear and quadratic components of the curves, both of which were very significant ($p < 0.001$ and $p < 0.005$). The additional training days 6-10 of group II were analyzed, but proficiency for the extra training days did not differ significantly from that at the end of day 5.

In training situations in which the task quickly becomes monotonous, such as sextant sighting, maintaining interest and motivation must be considered when performances are evaluated. The most interesting result in the training portion of the study was that the proficiency of both groups of naive subjects was comparable to that of the experienced group. This suggests that once an individual has reached his performance asymptote, his proficiency will remain very stable, assuming that other factors do not vary, for example, motivation. Therefore, extra training to further sharpen the sighting abilities of a subject may be a waste of time. Also, if a subject has not

performed the sighting task for an extended period of time, for example, six months or more, he may require virtually the same amount of refresher training to reach his proficiency asymptote as a naive subject.

Sighting on the Monochromatic Stars

A 4 (colors) by 15 (subjects) factorial design was used for the evaluation of performance differences in sighting on the colored stars (ref. 11). The dependent variable was the standard deviation of the subject's 16 angle readings. The standard deviation was used as the subject's score for each condition because it measures the consistency with which he made his sightings, and indicates the reliability of the sightings. Reference 1 provides a detailed explanation of the use of the standard deviation in this task.

¹Small p represents the probability of the event occurring by chance. For a further discussion, see reference 10, pages 202 and 249.

TABLE IV.- ANALYSIS OF VARIANCE
SUMMARY: COLORS

Source	df	MS	F
Colors (A)	3	56.03	20.98 ^a
Subjects (B)	14	7.46	
A×B	42	2.67	

^a $p < 0.001$.

TABLE V.- COMPARISONS OF THE COLOR
CONDITIONS USING SCHEFFE'S METHOD

Colors compared	A	F
Red vs. blue	114.85	43.01 ^a
Red vs. white	.92	N.S.
Red vs. red-green	66.72	24.98 ^b
Blue vs. white	95.19	36.65 ^a
Blue vs. red-green	6.50	N.S.
White vs. red-green	51.96	19.46 ^c

^a $p < 0.01$

^b $p < 0.05$

^c $p < 0.05$

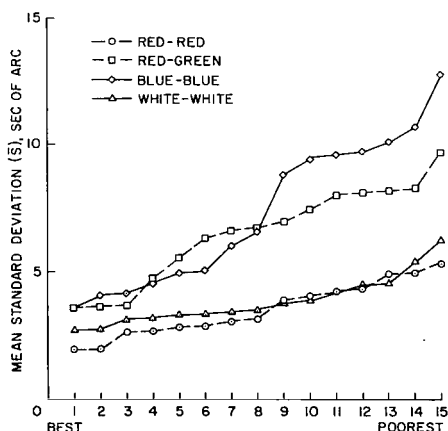


Figure 8.- Average ranked performance comparing color conditions.

Table IV presents the results of the analysis of variance for the color conditions and shows a significant difference ($p < 0.001$) between colors. Table V summarizes Scheffe's multiple comparison technique (ref. 9, p. 154) which tests the relationships between the color conditions. When both star targets were red or both were white, performance variability was significantly less than when both were blue, or one red and the other green. performance was worst when both stars were blue. No filters were used in the white-white condition, but voltage limitations when the stars were adjusted to plus one (+1) visual magnitude resulted in a color temperature much lower than the 2200° K originally measured at 2 V. Consequently, the white stars appeared to be more of a reddish-orange, and approximated the red condition.

One possible reason for the poor performance when two blue targets were used was the necessity to have subjects sight in this condition without the aperture in front of the objective lens of the telescope, while all other conditions had the aperture in place. Reference 1 presents evidence that stopping down the objective lens of the telescope significantly improves performance. However, in the blue-blue condition plus one (+1), visual magnitude targets could not be seen by some subjects when the aperture stop was in place.

The poor showing with the red-green condition, on the other hand (fig. 8), suggests that using different colors for each target may be a different task from the single-color conditions. Since the point-source targets could not be matched for brightness and hue, superimposition always resulted in some

of the original colors remaining visible. This, then, required the subject to add another individual criterion to his estimation of what superimposition should be. The difference in wavelength between the two colors may also have caused variation due to individual differences in accommodation.

CONCLUSIONS

The results of the study indicate that:

1. Five days of training are sufficient for achieving a performance asymptote when sextant sighting under the conditions of this study.
2. If monochromatic star targets may be used for sextant sightings, the least variability in human performance is associated with targets from the red end of the spectrum.

Ames Research Center

National Aeronautics and Space Administration

Moffett Field, Calif., 94035, Dec. 9, 1968

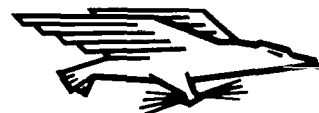
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